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(54) EXPENDABLE EBW FIRING MODULE FOR DETONATING PERFORATING GUN CHARGES

VERBRAUCHBARER ELEKTRISCHER BRÜCKENZÜNDERMODUL ZUR DETONATION VON PERFORATORLADUNGEN

MODULE DE MISE A FEU CONSOMMABLE A FIL EXPLOSE PERMETTANT DE FAIRE DETONER DES CHARGES DE PERFORATEUR

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US-A- 5 179 248

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Description

[0001] This invention relates to perforating gun detonation apparatus, and more particularly to exploding bridgewire (EBW) detonators and safe circuits for firing such EBW detonators. A conventional electric detonator of the kind in general use by wireline service companies for use in oil and gas well perforating activities typically contains a bridgewire embedded in an ignition mix, plus a primer charge and a base charge. The primer charge is a sensitive explosive, usually lead azide and the base charge is the same explosive material used in detonating cord and shaped charges, usually RDX or HNS. When sufficient current is applied through the detonator leads to the bridgewire it ignites the ignition mix, which in turn ignites the primer charge. The exploding primer charge causes the base charge to detonate.

[0002] The main drawbacks of such electric detonators are:

1. They contain sensitive primary explosives, and must be handled carefully to avoid accidental initiation by mechanical impact; and
2. They are easily fired electrically, requiring only the application of 0.5 A or less for a few milliseconds. Accordingly, they are particularly susceptible to any source that could provide this power accidentially, such as electric welding equipment, radio transmitters, cathodic protection systems and faulty rig machinery and equipment. To protect against such spurious electrical power, all possible equipment and machines that could produce such stray power often had to be shut down for extended periods, and the wellhead and rig structure monitored for stray voltages.

[0003] By contrast, Exploding Bridgewire (EBW) detonators contain no primary explosive, which makes them insensitive to initiation by mechanical impact and therefore safer to handle than conventional detonators. In addition, they are immune by the external power sources usually on the well or rig site. However, to fire an EBW detonator successfully requires the use of a specialized electronic circuit. That electronic circuit can pick up spurious AC, radio frequency (RF) and DC voltages from the many rig sources named above, including lightning strikes that can accidentally cause the EBW detonator to be fired. Such detonators are described, for example, in US Patents Nos. 5,173,570 and 5,179,248.

[0004] Accordingly, it is necessary to design the electronic firing circuits for EBW detonators to include safety circuits for isolating the detonator firing circuit from such spurious voltages to prevent accidental detonation of the perforating gun charges.

[0005] According to the present invention there is provided an expendable EBW firing module, for use in connection with a conventional perforating gun system including a source of DC power at the surface to be supplied to the perforating gun system through a wireline cable interconnected thereto, without requiring any additional perforating gun hardware, the firing module comprising:

a high-voltage multiplier circuit for multiplying a first voltage related to the voltage received from the DC power source by a predetermined multiple to generate a second DC voltage capable of detonating an EBW detonator;
a firing circuit for receiving said second DC voltage from said multiplier circuit for application to the EBW detonator; and
an electronic safety circuit coupled to the multiplier so that it will be interposed between the DC power supply at the surface and said multiplier circuit for preventing unintentional activation of the multiplier circuit by stray AC/RF and DC voltages present at the wellsite,
said expendable module being adapted for mounting directly in the interior housing of a conventional perforating gun system directly adjacent the EBW detonator without protection from the perforating gun charge blast,

characterised in that the multiplier has an AC input and in that the safety circuit comprises means for converting DC voltage in the safety circuit to AC voltage for input to the multiplier circuit.

[0006] In order that the manner in which the above-recited principles and features of the invention are attained can be understood in detail, a more particular description of the invention may be had by reference to specific embodiments thereof which are illustrated in the accompanying drawings, which drawings form a part of this specification.

[0007] In the drawings:

[0008] Fig. 1 is an illustrative drawing showing a wireline perforating tool disposed in a wellbore and utilizing the expendable EBW firing module according to the present invention.

[0009] Fig. 2 is a block diagram showing the major assemblies of the wireline perforating tool utilizing the expendable EBW firing module according to the present invention.

[0010] Fig. 3 is a detailed schematic diagram of the preferred embodiment of the expendable EBW firing module according to the present invention.

[0011] Fig. 4 is a detailed schematic diagram of another embodiment of the expendable EBW firing module according to the present invention.

[0012] Fig. 5 is a vertical diagrammatic view, partly in cross-section, of a wireline perforating gun system utilizing the expendable EBW firing module in accordance with this invention.

[0013] Fig. 6 is a cross-sectional view of one embodiment of protective packaging for the expendable EBW firing module.

[0014] Referring to Figs. 1 and 2, a wireline perforating gun system 10, including the expendable EBW firing module 24, is shown disposed in a borehole 14 that has been drilled in earth formation 12. The perforating gun tool 10 is shown spaced adjacent steel casing 16 that has been set in the borehole 14 adjacent a formation of interest 13. The tool 10 is supported by a conventional single- or multi-conductor wireline cable 18 that travels over a sheave 26 and is spooled onto a winch drum 28. The perforating tool 10 is raised and lowered in the borehole 14 by the action of the cable drum 28 and the "spooling out" of the cable 18 to lower the gun system 10 in the borehole, or the "spooling in" of cable 18 to raise the perforating gun system 10 in the borehole 14. Depth measurements are made from the travel of the wireline cable 18 as it passes over the sheave 26 and communicated to the surface control equipment 30 via cable or conductor 32. Electrical power for operating the perforating gun system 10, including the necessary control signals for firing the tool, are applied through cable 18 from the control equipment 30. The perforating gun system 10 includes a perforating gun section 20, an electronic bridge wire (EBW) detonator and booster section 22, the expendable EBW firing module 24 according to the present invention cooperating with the EBW section and a cablehead 25 interconnected to the cable 18 and the control panel 30. As will hereinafter be described in greater detail, and as more particularly shown in Fig. 2, the expendable EBW firing module 24 comprises a safety circuit 35, a voltage multiplier circuit 37 and a firing circuit as more particularly shown in Fig. 3. The expendable EBW firing module 24 receives DC power for operating the EBW and booster section 22 for firing the perforating gun system 20 from a DC power supply 40 disposed in the surface control equipment 30 transmitted via the single- or multi-conductor cable 18 and cablehead 25.

[0015] Referring now to Figs. 1, 2 and 3, the operation of the preferred embodiment of the expendable EBW firing module 24 will be described in detail. DC electrical power is applied from the DC power supply 40 in the surface equipment 30 through the cable 18 and cablehead 25 to the input of the safety circuit 35. The DC power (200 VDC) is applied to one side of a surge voltage protector (SVP) 41, the SVP 41 rated at 600 volts. The SVP will conduct and connect the input of circuit 35 directly to ground potential (the perforating gun housing) at 48 in the event of an applied voltage surge in excess of 600 VDC, such as in the case of a lightning strike nearby to the perforating gun system 10 or other DC power interference at the well site.

[0016] The 200 VDC applied across the SVP 41 is also applied across a resistor 44 and a series connected LED 46, a capacitor bank 50-50' and to the positive side of a diode 52. The capacitor bank 50-50' appears as an open circuit to DC power, but will react with radio frequency (RF) and AC power as a low impedance path to shunt any RF/AC applied as an input to the circuit 35 to ground at 48. While the capacitor bank 50-50' is shown comprising several capacitors in series, the capacitor bank could be replaced with a single capacitor that is rated the same as the combined capacitance of the bank 50-50'. Resistor 44 acts as a bleed resistor for the capacitor bank 50-50', and as a current limiting resistor for the LED 46. The fuse 42 is rated at 125 mA and any significant stray RF or AC voltage will cause a current in excess of the rating of fuse 42 which will blow the fuse and disable the circuit. Such AC and/or RF inputs might be caused by adjacent power generating machinery, radio transmitters, radar equipment, faulty rig wiring or equipment or other like sources that may be present at the well site. The LED will conduct when any current is flowing through resistor 44, and is particularly useful as a power indicator when testing the circuit on the surface prior to lowering the perforating tool into the well bore.

[0017] As power is applied to the circuit 35, the diode 52 conducts and applies the DC voltage to the anode of the SCR 58. As soon as the voltage across the Zener diodes 56 and 56' reaches 150 VDC, the SCR 58 is switched on and acts as a basic "short circuit" to permit current to pass without offering any significant impedance. The SCR 58 thus acts as a "switch" to sharply turn "on" when 150 VDC appears across the anode and gate legs of the SCR. This acts as a safety feature to prevent other stray DC voltages under 150 VDC, such as may be caused by a welding machine or other DC machinery at the well site, from passing through to the voltage multiplier circuit 37 and activating it. The resistor 60 is a bias resistor to achieve positive shut-off of the SCR when the applied voltage is removed from the anode.

[0018] The remaining components of the safety circuit 35 comprise a self-triggering multivibrator circuit for applying an AC input signal to the voltage multiplier circuit 37 as will hereinafter be further described. The heart of the multivibrator circuit are the pair of transistors 66 and 68, the collectors of each of which are connected as an input to the multiplier circuit 37 through conductors, 80 and 78, respectively. The resistors 62 and 64 are current limiting resistors, and resistors 70 and 72 act as biasing resistors for the base inputs 66' and 68' of the transistors 66 and 68, respectively. The capacitors 74-74' and 76-76' couple the bases 66' and 68' of each transistor to the collector of the other transistor. The output of the multivibrator circuit is an approximate sine wave that is applied to the input of the voltage multiplier circuit 37 via conductors 78 and 80.

[0019] The voltage multiplier circuit 37 is a conventional stacked voltage doubler circuit that will receive an input of 200 VAC and multiply the voltage by a predetermined value, in this case eight, and generate an output of 1600 VDC

applied through diode 99 and input resistor 104, to resistor 100 in parallel with capacitor 102 of the firing circuit 39. The resistor 100 is a bleed resistor for the capacitor 102 while resistor 104 acts as a current limiting resistor. In series with resistor 104 is another SVP 106, which is rated at 1500 VDC, and which will conduct when capacitor 102 has reached a voltage of 1500 VDC to apply the 1500 VDC in a time interval of 1 μSec to the output of the firing circuit 39 to the EBW and booster in 22 for actuating the EBW and firing the perforating guns. A resistor 108 is placed in parallel with SVP 106 between the output of the circuit 39 and the capacitor 102 for acting as a bleed resistor for capacitor 102 and to permit direct voltage reading across the firing storage capacitor 102 for testing purposes. During testing at the surface prior to the time the expendable EBW firing module 24 is attached into the circuit of the perforating gun system 10, a load resistor (or a dummy EBW) may be tied to the output leads of the firing circuit 39 and the rated 200 VDC applied to the input of the safety circuit 35. A test voltmeter may also be attached across the output leads of the circuit 39 and a measurement of the voltage appearing across capacitor 102 may be made to verify that the circuit is functioning properly. The inductor 54 functions to protect the multivibrator circuit described above from large voltage spikes that may be conducted through the grounding connections of the tool when the capacitor 102 is discharged. This protection is only necessary during testing, since the expendable EBW firing modulewill be damaged beyond repair upon actual detonation of the EBW and the firing of the perforating guns.

[0020] Referring now to Figs. 1, 2 and 4, the operation of another embodiment of the expendable EBW firing module 24 will be described in detail. DC electrical power is applied from the DC power supply 40 in the surface equipment 30 through the cable 18 and cablehead 25 to the input of the safety circuit 35'. The DC power (200 VDC) is applied to one side of a surge voltage protector (SVP) 141, the SVP 141 being rated at 600 volts, and functioning in the same manner as SVP 41 in the circuit of Fig. 3 as hereinabove described to conduct and connect the input of circuit 35 directly to ground potential (the perforating gun housing) at 148 in the event of an applied voltage surge in excess of 600 VDC, such as in the case of a lightning strike nearby to the perforating gun system 10 or other DC power interference at the well site.

[0021] The 200 VDC applied across the SVP 141 is also applied across a capacitor 150 and to a fuse 142. The capacitor 150 appears as an open circuit to DC power, but will react with radio frequency (RF) power to create a low impedance path to shunt RF power applied as an input to the circuit 35 to ground at 48. Diodes 152 and 153 conduct and apply the DC power to an AC voltage shunt circuit comprising capacitor 144, and cascaded transistors 146 and 149. AC current will pass through the capacitor 144 and be applied to the base of the first transistor 146 via lead 147, causing the transistor to conduct. When transistor 146 conducts, the second transistor 149 is switched on, causing the applied voltage to be shunted to ground. With an AC voltage of about 30 V and 60 Hz, enough current will flow through the transistor 149 to blow the fuse 142, thus disabling the circuit. Such AC and/or RF inputs might be caused by adjacent power generating machinery, radio transmitters, radar equipment, faulty rig wiring or equipment or other like sources that may be at the well site. Resistors 156 and 157 act as current limiting resistors to prevent the activation of the IC 158 until approximately 130 VDC has been applied from power supply 40. The Zener diodes 169, 170 and 171 act to prevent voltages below approximately 150 VDC from being passed to the voltage multiplier circuit 37'.

[0022] The resistors and capacitors 159, 160, 161, 162, 163 and 164 form other resistive and capacitance values for biasing the selected IC circuit 158 and to preselect the frequency and the pulse width of the generated pulse signal train for applying AC triggering pulses to the to transistor 168 as will hereinafter be further described. The pulse train output of the IC circuit 158 is applied through current limiting resistor 165 to the base of transistor 168 which conducts on the occurrence of each pulse. A Zener diode 166 is interconnected between the base and emitter of the transistor 168 to prevent an overvoltage appearing thereacross. The transistor 168 acts as a switch only to rapidly pulse the current through the inductor 172. The rapidly rising and collapsing electromagnetic fields in inductor 172 caused by the pulsed current therethrough generate a series of high-voltage spikes, which act as the input of the stacked voltage doubler circuit as hereinabove described.

[0023] The voltage multiplier circuit 37 is a conventional stacked voltage doubler circuit that will receive the output across inductor 172 and multiply this voltage by a predetermined multiplier factor to generate an output of 1600 VDC applied through diode 199 as an input to resistor 204, and to resistor 200 in parallel with capacitor 202 of the firing circuit 39'. The resistor 200 is a bleed resistor for the capacitor 202 while resistor 204 acts as a current limiting resistor. In series with resistor 204 is another SVP 206, which is rated at 1500 VDC, and which will conduct when capacitor 202 has reached a voltage of 1500 VDC to apply the 1500 VDC in a time interval of 1 uSec to the output of the firing circuit 39' to the EBW and booster in 22 for actuating the EBW and firing the perforating guns. A resistor 208 is placed in parallel with SVP 206 between the output of the circuit 39 and the capacitor 202 for acting as a bleed resistor for capacitor 202 and to permit direct voltage reading across the firing storage capacitor 202 for testing purposes.

[0024] During testing at the surface prior to the time the expendable EBW firing module 24 is attached into the circuit of the perforating gun system 10, a load resistor (or a dummy EBW) may be tied to the output leads of the firing circuit 39 and the rated 200 VDC applied to the input of the safety circuit 35. A test voltmeter may also be attached across the output leads of the circuit 39 and a measurement of the voltage appearing across capacitor 202 may be made to verify that the circuit is functioning properly. The inductor 154 functions in the same manner as inductor 54 as herein-

above described in connection with Fig. 3 for protecting the IC circuit 158 from large voltage spikes that may be conducted through the grounding connections of the tool when the capacitor 202 is discharged. As described above, this protection is only necessary during testing, since the expendable EBW firing modulewill be damaged beyond repair upon actual detonation of the EBW detonator.

[0025] Components for the circuits described above are given in the following table:

Table 1

Component Values	
Ref. No.	Component
41, 141	SVP 600 VDC
42	Fuse 125 ma
142	Fuse 100 ma
50, 50'	Capacitor, 47 uF
52, 152, 153, 86, 87, 88, 89, 90, 91, 92, 93, 99, 186, 187, 188,189, 190, 191 & 199	Diode 1N4249 1000 V, 1 A
54, 154	Inductor, 1000 uH
56, 56'	Zener diode, 75 V
58	SCR, MCR100-6
60	Resistor, 10 K
62, 64	24.9 K
66, 68	Transistor, MJE13007
70, 72	Resistor 464 K
74, 74' 76 & 76'	Capacitor, 0.001 uF
82, 83, 84, 85, 86, 94, 95, 96, 97, 98, 164, 182, 183, 184, 194, 195, 196 & 198	Capacitor, 0.01 uF
100, 200	Resistor, 390 M
102	Capacitor, 0.32 uF, 2000 V
202	Capacitor, 0.27 uF, 2000 V
104, 202	Resistor, 150 K
106, 206	SVP, 1500 VDC
108, 208	Resistor, 390 M
144	Capacitor, 0.01 uF
146, 149 & 168	Transistor, MPSA42
156	Resistor, 30 K
157	Resistor, 36 K
158	Integrated Circuit (IC) TL494
159	Resistor, 10 K
160	Resistor, 45.3 K
162	Capacitor, 1 uF
163	Resistor, 37.4 K
165	Resistor, 1K
166, 169, 170 & 171	Zener diode, 51 V
172	Inductor, 50 mH

[0026] Referring now to Figs. 1, 2 and 5, a portion of the perforating gun system 10 is shown comprising a portion of the perforating gun section 20, showing the typical perforating shaped charges 225 supported by a charge carrier (not shown for simplicity) distributed vertically in the gun section 20. A hollow nose plug 20' is shown attached to the lower end of the perforating gun section 20 by means of a threaded connection 21. An electrical power conductor from cablehead 25 (Figs. 1 and 2) and a primacord 225 interconnecting the shaped charges 235 terminate below a bulkhead 227 at the end of the gun section 20. The expendable EBW firing module 24 is connected to the power conductor (+) and to the gun section body for ground (-), and the EBW and booster 22 are connected to the primacord. A pair of conductors 228 and 230 connect the output of the firing circuit 39 of the expendable EBW firing module 24 to the EBW 22. When the expendable EBW firing module 24 detonates the EBW to set off the shaped charges 235 of the perforating gun section 20, the force of the EBW and booster charge 22 blast will substantially destroy the module 24. When the perforating gun is returned to the surface, the gun section 20 will be replaced, new charges 235 loaded, and a new

expendable EBW firing module 24 and EBW and booster charge 22 mounted and interconnected for firing the perforating charges as hereinabove described.

[0027] Of course, the expendable EBW firing module 24 and the associated EBW 22 may be mounted either below the gun section 20 as shown in Fig. 5, or above the gun section as preferred. If a second gun section is being carried in the perforating gun system for perforating multiple formation vertical intervals, a second expendable EBW firing module24 may be attached to the electrical power conductor 226 for the second device with the (+) and (-) terminals reversed and the second circuit 24 will fire upon the application of a negative DC power input.

[0028] The circuits 35, 37 and 39 that make up the expendable EBW firing module 24 are mounted on a single circuit board and comprise a size of approximately 5 inches by 5/8 inches, and may be packaged in a selected packaging material for protecting the expendable module during transit and handling. Fig. 6 shows an example of such packaging, in wich the module 24 is shown comprising a single circuit board 250 upon which is mounted electrical circuit components such as shown at 252 is encased in a plastic resin materail 254. The plastic resin material 254 may also comprise any other selected packaging material that will serve the necessary purpose of protecting the circuit board 250 and components 252, such as a plastic tubing "shrink-wrapped" onto the circuit board or mounted within a heavier plastic tubing. A pair of conductors 256 and 258 would extend from the module 24 for attaching the module to the power input cord 226 (Fig. 5) and the tool housing and for interconnection to the EBW and booster charge section 22.

[0029] Numerous variations and modifications may be made in the structure herein described without departing from the present invention. Accordingly, it should be claerly understood that the forms of the invention herein described and shown in the figures of the accompanying drawings are illustrative only and are not intended to limit the scope of the invention, as defined in the appended claims.

Claims

1. An expendable EBW firing module, for use in connection with a conventional perforating gun system including a source of DC power at the surface to be supplied to the perforating gun system through a wireline cable interconnected thereto, without requiring any additional perforating gun hardware, the firing module comprising:

   a high-voltage multiplier circuit (37) for multiplying a first voltage related to the voltage received from the DC power source by a predetermined multiple to generate a second DC voltage capable of detonating an EBW detonator;
   a firing circuit (39) for receiving said second DC voltage from said multiplier circuit for application to the EBW detonator; and
   an electronic safety circuit (35) coupled to the multiplier (37) so that it will be interposed between the DC power supply at the surface and said multiplier circuit for preventing unintentional activation of the multiplier circuit by stray AC/RF and DC voltages present at the wellsite,

   said expendable module being adapted for mounting directly in the interior housing of a conventional perforating gun system directly adjacent the EBW detonator without protection from the perforating gun charge blast,
   characterised in that the multiplier has an AC input and in that the safety circuit comprises means (66, 68) for converting DC voltage in the safety circuit to AC voltage for input to the multiplier circuit.

2. A module according to claim 1, wherein the safety circuit (35) comprises a series fuse (42).

3. A module according to claim 1 or 2, wherein the safety circuit (35) comprises a surge voltage protector (41).

4. A module according to claim 1, 2 or 3, wherein the safety circuit (35) comprises a shunt RF path to shunt RF/AC power.

5. A module according to claim 1, 2, 3 or 4, wherein the safety circuit (35) comprises means (58) for isolating the multiplier circuit until the input DC voltage reaches a given level.

6. A wireline perforating tool having a firing module according to any of the preceding claims.

Patentansprüche

1. Verbrauchbares EBW-Zündungsmodul zur Verwendung in Verbindung mit einem bekannten Perforator-Kanonen-

system, mit einer Gleichspannungsquelle an der Oberfläche zum Anlegen einer Gleichspannung an das Perforator-Kanonensystem mittels eines damit verbundenen Drahtleitungskabels, wobei keine zusätzliche Perforator-Kanonen-Hardware benötigt wird, und das Zündungsmodul aufweist:

eine Hochspannungs-Multiplizierschaltung (37) zum Multiplizieren einer ersten Spannung, die mit der von der Gleichspannungsquelle erhaltenen Spannung in Beziehung steht, um ein vorbestimmtes Vielfaches, um eine zweite Gleichspannung zu erhalten, mit der ein EBW-Detonator detonierbar ist;
eine Zündungsschaltung (39) zum Empfangen der zweiten Gleichspannung von der Multiplizierschaltung, um damit den EBW-Detonator zu beaufschlagen: und
eine elektronische Sicherheitsschaltung (35), die derart an die Multiplizierschaltung (37) gekoppelt ist, dass sie zwischengeschaltet ist zwischen die Gleichspannungsquelle an der Oberfläche und die Multiplizierschaltung, um ein unbeabsichtigtes Aktivieren der Multiplizierschaltung durch in der Bohrung auftretende Wechselspannungs-/Radio-Frequenz- und Gleichspannungs-Störspannungen zu verhindern,
wobei das verbrauchbare Modul derart ausgelegt ist, dass es direkt in das Gehäuseinnere eines bekannten Perforator-Kanonensystems und direkt neben den EBW-Detonator ohne Schutz vor der Perforator-Kanonen-Ladungssprengung montierbar ist,

dadurch gekennzeichnet, dass der Multiplizierer einen Wechselspannungs-Eingang aufweist und dass die Sicherheitsschaltung eine Einrichtung (66, 68) zum Umwandeln einer Gleichspannung in der Sicherheitsschaltung in eine Wechselspannung als Input für die Multiplizierschaltung aufweist.

2. Modul nach Anspruch 1, **dadurch gekennzeichnet,** dass die Sicherheitsschaltung (35) eine Reihen-Sicherung (42) aufweist.

3. Modul nach Anspruch 1 oder 2, **dadurch gekennzeichnet,** dass die Sicherheitsschaltung (35) einen Stoßspannungs-Schutz (41) aufweist.

4. Modul nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, dass die Sicherheitsschaltung (35) einen Shunt-RF-Kanal zum Shunten von RF-/AC-Spannung aufweist.

5. Modul nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** dass die Sicherheitsschaltung (35) Mittel (58) zum Isolieren der Multiplizierschaltung bis zum Erreichen eines bestimmten Schwellenwerts durch die Eingangs-DC-Spannung aufweist.

6. Drahtleitungs-Perforatorwerkzeug mit einem Zündungsmodul nach einem der vorstehenden Ansprüche.

Revendications

1. Module de mise à feu consommable à "fil explosé", ou cordeau détonant, utilisable avec un perforateur conventionnel à charges détonantes, comprenant, au sol, une source d'énergie à courant continu destinée à être appliquée au perforateur par un câble électroconducteur relié à celui-ci, sans nécessiter du perforateur un matériel supplémentaire, le module de mise à feu comprenant :

un circuit multiplicateur haute tension (37) pour multiplier une première tension reliée à la tension reçue depuis la source d'énergie en courant continu, par un multiple prédéterminé pour générer une seconde tension en courant continu capable de faire détoner un cordeau détonant;
un circuit de mise à feu (39) pour recevoir dudit circuit multiplicateur la dite seconde tension continue et l'appliquer au cordeau détonant, et
un circuit de sécurité électronique (35) couplé au multiplicateur (37) de manière telle qu'il soit interposé entre l'alimentation au sol en énergie en courant continu et le dit circuit multiplicateur pour empêcher l'activation non intentionnelle du circuit multiplicateur par des parasites de courant alternatif ou de radio fréquence, ou par des tensions continues présentes sur le site du puits, le dit module consommable étant conçu pour être monté directement à l'intérieur du boîtier du système de charges du perforateur conventionnel directement adjacent au cordeau détonant sans protection par rapport aux explosions du perforateur,

caractérisé :

en ce que le multiplicateur a une entrée en courant alternatif et
en ce que le circuit de sécurité comprend des moyens (66,68) pour convertir la tension continue du circuit de sécurité en une tension alternative comme entrée du circuit multiplicateur.

2. Module selon la revendication 1, dans lequel le circuit de sécurité (35) comprend un fusible monté en série (42) ;

3. Module selon l'une quelconque des revendications 1 ou 2, dans lequel le circuit de sécurité (35) comprend un protecteur (41) de tension de choc;

4. Module selon l'une quelconque des revendications 1, 2 ou 3, dans lequel le circuit de sécurité (35) comprend un circuit de dérivation de radiofréquence pour dériver l'énergie radiofréquence/courant alternatif.

5. Module selon l'une quelconque des revendications 1, 2, 3 ou 4, dans lequel le circuit de sécurité (35) comprend des moyens (58) pour isoler le circuit multiplicateur jusqu'à ce que la tension d'entrée continue atteigne un niveau donné ;

6. Outil de perforation à ligne conductrice ayant un module de mise à feu selon l'une quelconque des revendications précédentes.

FIG. 1

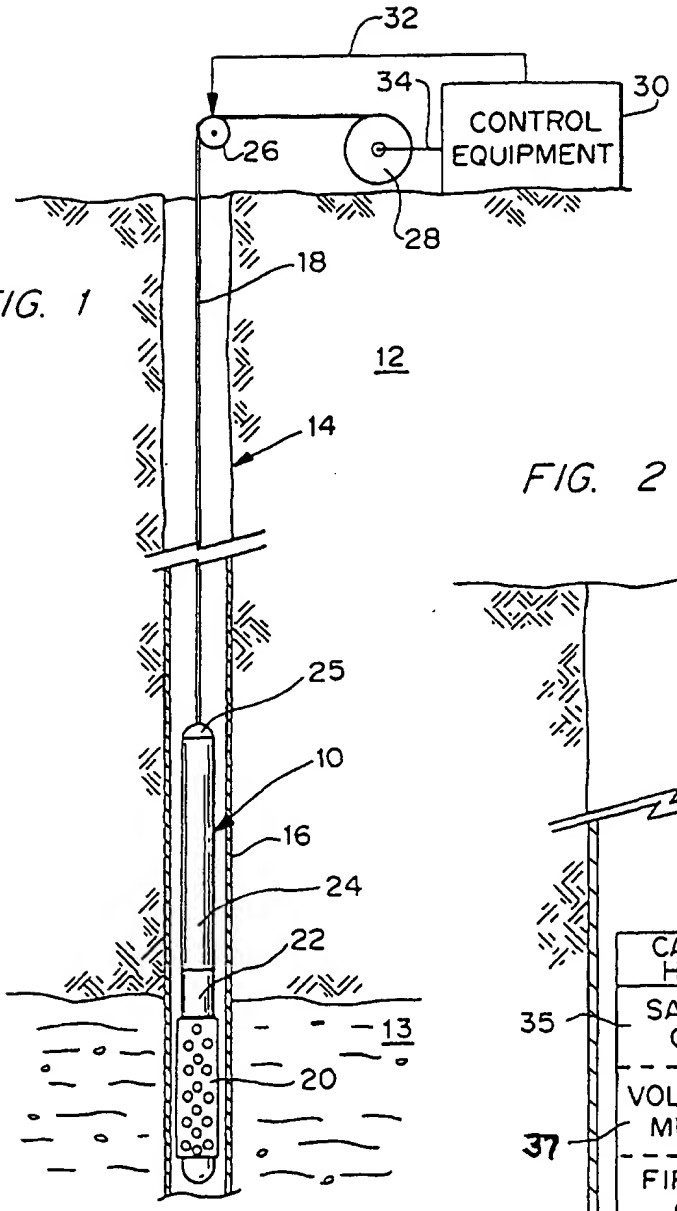
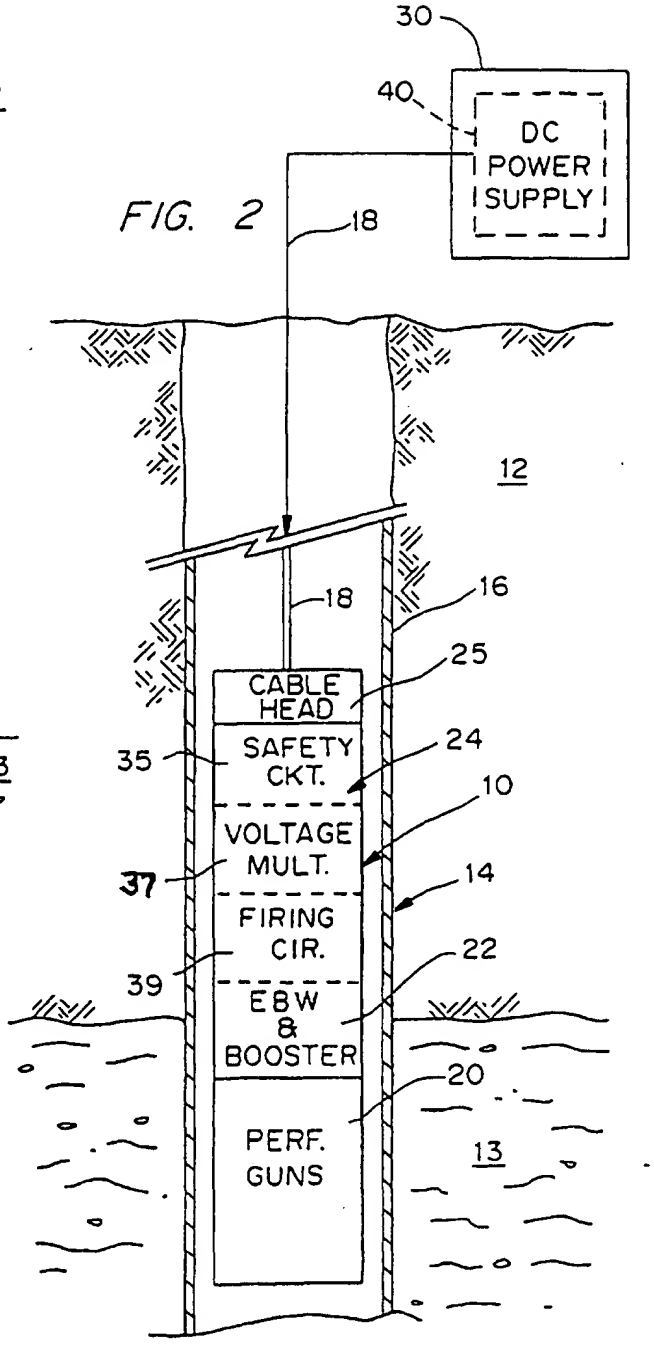
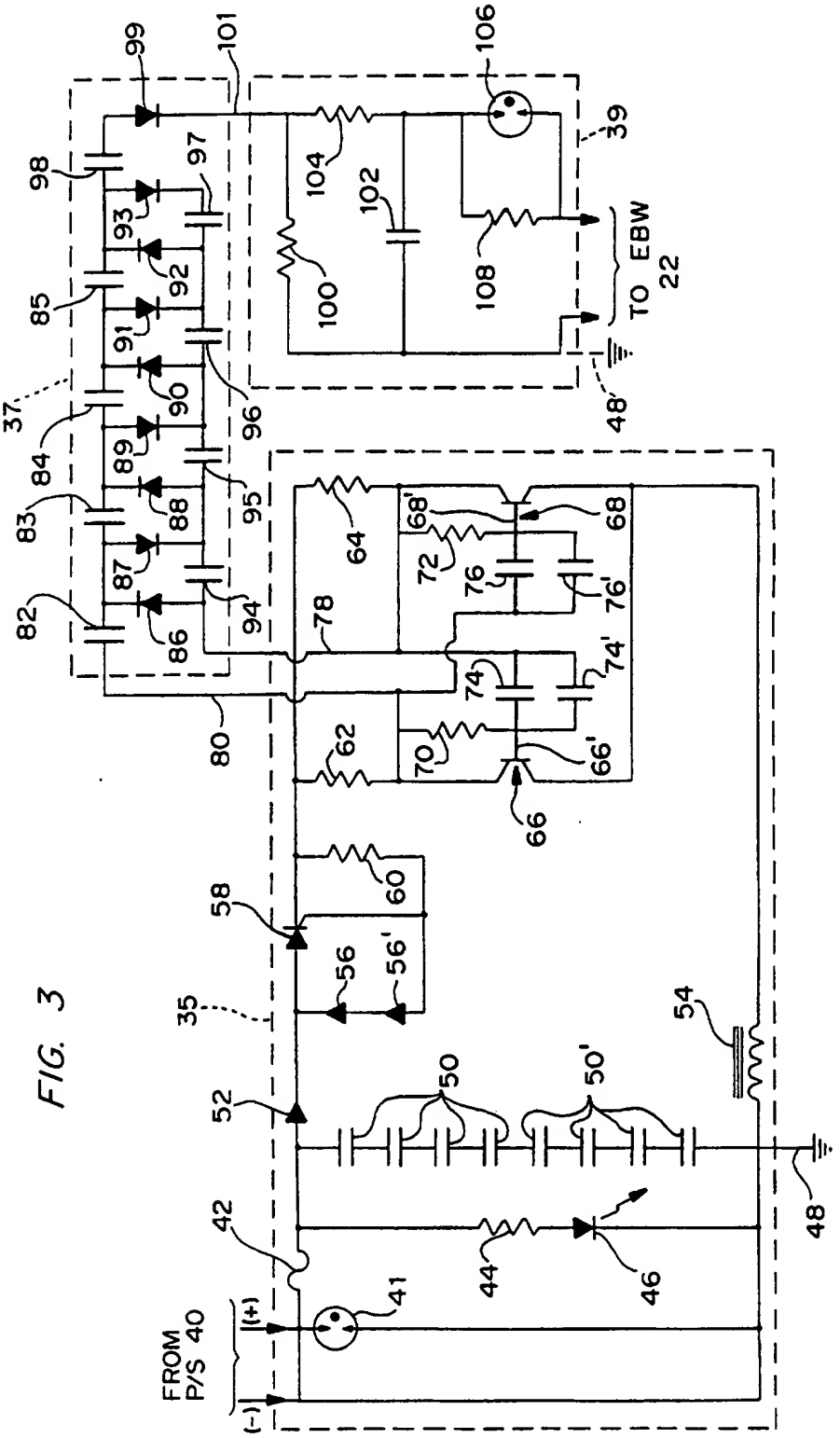

32
34
30
CONTROL EQUIPMENT
26
28
18
12
14
25
10
16
24
22
13
20

FIG. 2


30
40
DC POWER SUPPLY
18
12
16
25
CABLE HEAD
35
SAFETY CKT.
24
10
VOLTAGE MULT.
37
14
FIRING CIR.
39
22
EBW & BOOSTER
20
PERF. GUNS
13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93
92
100
108
TO EBW
22
85
91
90
37
96
48'
84
89
95
64
68'
68
83
88
72
76
76'
87
82
86
94
78
74'
74
80
62
70
66'
66
60
58
56
56'
35
54
50
50'
52
48
42
44
46
41
FROM
P/S 40
(+)
(-)

FIG. 3

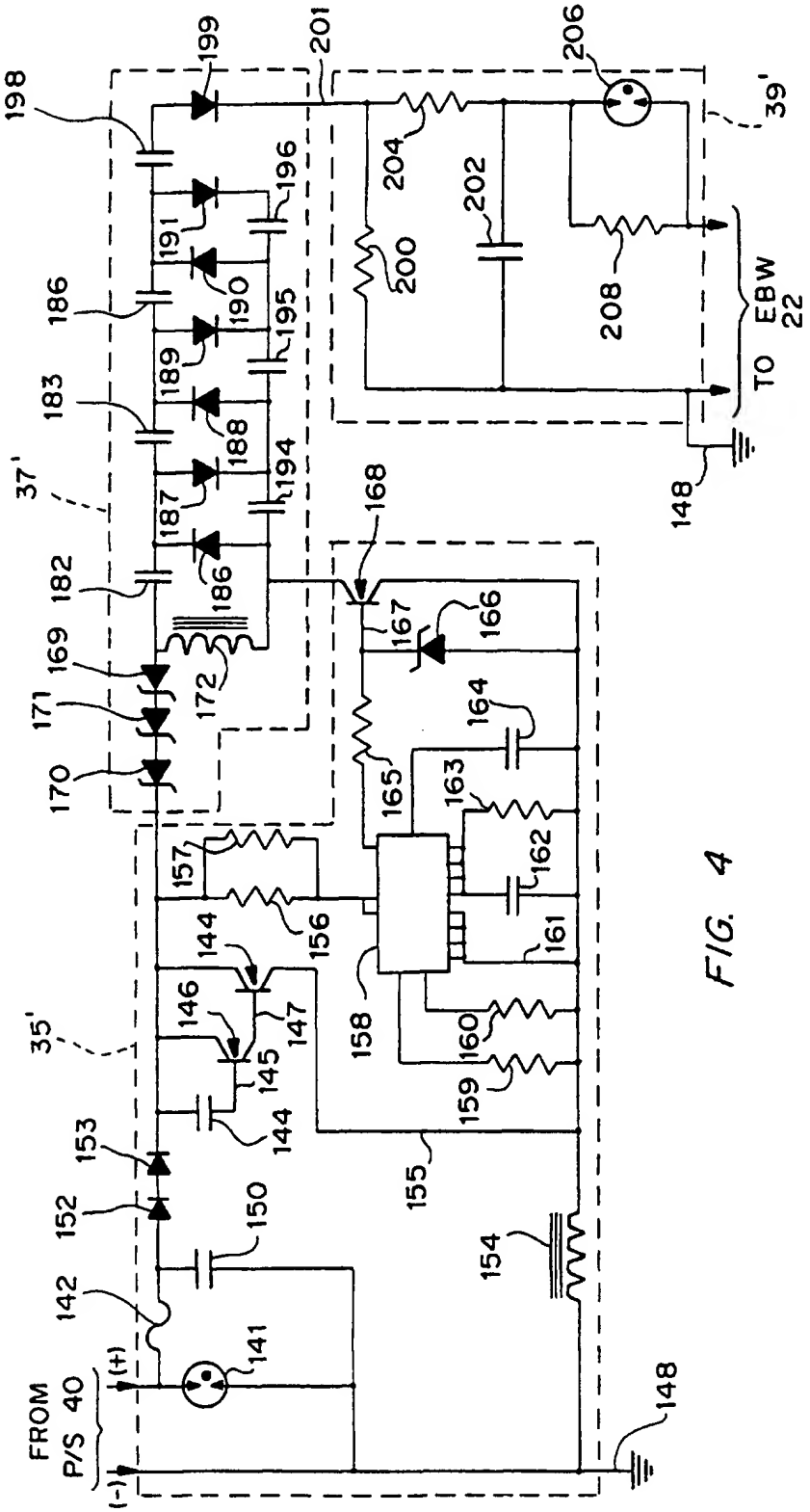
198
199
201
206
39'
204
202
200
208
TO EBW 22
148
37'
168
167
166
164
165
163
162
161
158
160
159
155
154
157
156
144
146
147
145
35'
153
152
150
142
141
FROM P/S 40
(+)
(-)
148
169
171
170
172
182
186
183
189
188
187
191
190
196
195
194

FIG. 4

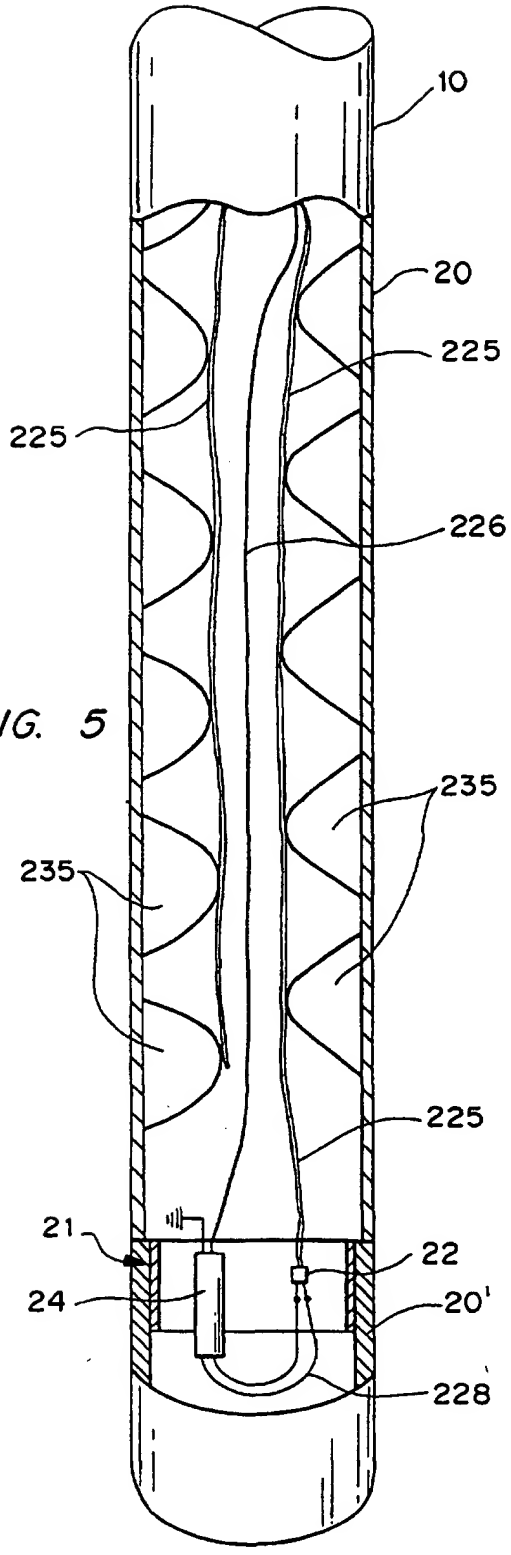
10
20
225
225
226
235
235
225
21
22
24
20'
228

FIG. 5

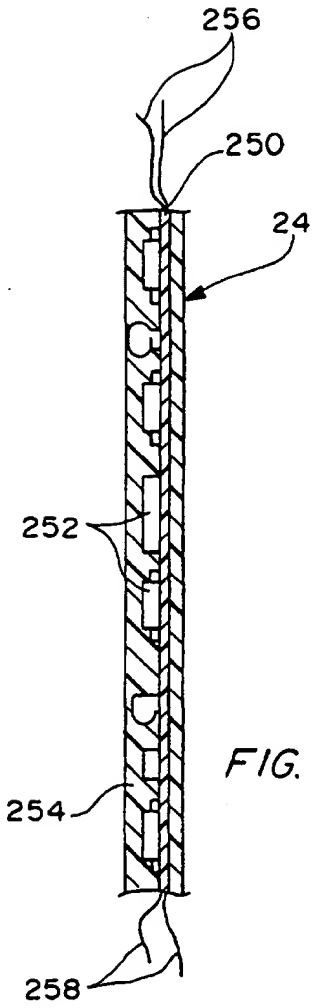
256
250
24
252
254
258

FIG. 6